REPORTS

The Little Ice Age and Coastal Southern California Human Economy

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Lowered mean temperatures, glacial advances, expansion of polar pack-ice, and tree-line retreats characterize a period of predominantly cool climate known as the Little Ice Age, ca. A.D. 1400-1850 (Calder 1975; Gribbin and Lamb 1978). This interval of climatic deterioration coincided with widespread disruption of human subsistence economies. Especially affected were hunter-gatherers inhabiting northern latitudes (e.g., Thule Eskimo), but the climatic change also impacted sedentary populations practicing relatively intensive agriculture in more temperate regions (Lamb 1977; Kington 1980; Lindgren and Neumann 1981). Decreased sunspot activity (Bray 1965, 1971; Eddy 1977; Stuvier and Quay 1980) and increased volcanism on earth (Bray 1974; Schneider and Mass 1975), both of which may reflect a reduction in the amount of solar energy reaching the planet, also occurred during the Little Ice Age. Mounting evidence supports the hypothesis that climatic fluctuations during the Holocene have been the result of varying levels of solar activity (Denton and Karlén 1973; Druffel 1982). Lamb (1977) estimated that a decrease in solar radiation of less than one percent from the preceding Little Climatic Optimum would have been sufficient to cause the worsened conditions.

We are interested in determining the magnitude of cooling in coastal southern California during the Little Ice Age, since the regional archaeological record does not appear to indicate major subsistence disruption among indigenous hunter-gatherer populations at that time. Koerper (1981), in fact, interpreted available prehistoric settlement data as showing generally increasing sedentism throughout the Holocene along the coast with no suggestion of late period deviation from this trend.

Previous work (Killingley and Berger 1979) has shown that oxygen isotopic analysis of dated *Mytilus californianus* shell, by measuring the ^{18}O content of its calcite, can provide a record-by-proxy of past oceanwater temperatures in the range of interest. Accordingly, fragments of *M. californianus* shell from an archaeological midden deposit (CA-ORA-855) in San Juan Capistrano (Fig. 1) were subjected to isotopic analysis. The site may represent remains of the historically recorded Juaneño village of *Putuidem* (O'Neil and Evans 1980). Excavations at CA-ORA-855 (Koerper and Drover 1983) also revealed evidence of prehistoric occupation, apparently dating to the latter half of Wallace's (1955) Late Prehistoric Horizon as suggested by the recovery of numerous Cottonwood Triangular projectile points, a single "Sonoran"-style

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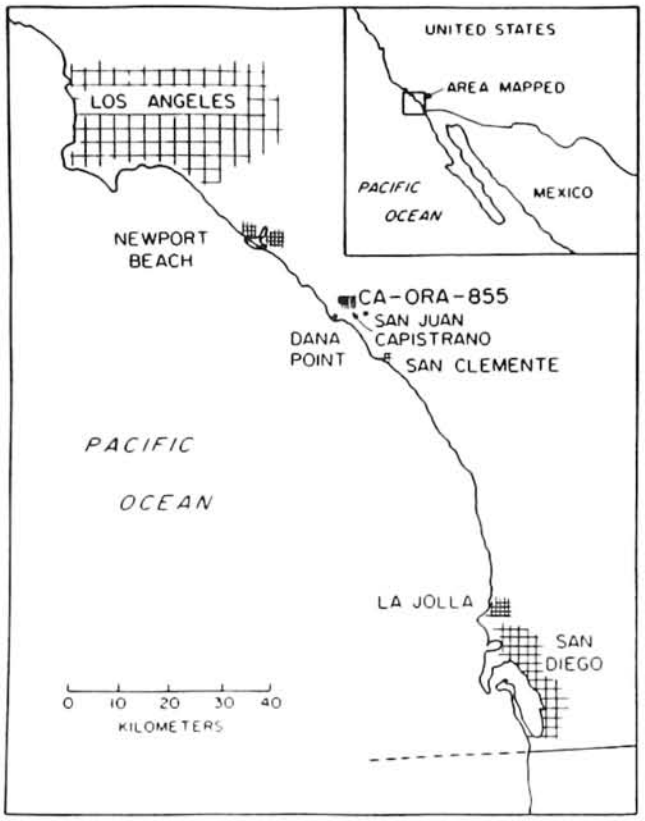

Fig. 1. Map of coastal southern California showing location of CA-ORA-855.

point, and the absence of all other known late-period point forms. Additional temporal indicators found at the site include Tizon Brown ceramic sherds and a high proportion of sidewall - to - spire - ground *Olivella* shell beads. Nine radiocarbon determinations, corrected for fractionation and reservoir effects, corroborate the artifactual cross-dating and place site occupation from about the 14th century A.D. to Euroamerican contact in the late 18th century – roughly the duration of the Little Ice Age.

Each shell was cleaned of surface debris ultrasonically and by scraping. Calcite samples were then removed, using a 0.5 mm.-diameter drill at roughly 2.0 mm. intervals starting at the ventral edge and working back along the growth surface. A relatively large number of samples (an average of 14) were obtained from each specimen to ensure that at least one annual growth cycle was represented. Fourteen shells from the site were sampled in this manner, as were three modern *M. californianus* shells. The latter were collected alive close to the outlet of San Juan Creek near Dana Point, presumably an area where local Juaneño would have gathered the molluscs. All of the calcite samples were baked under vacuum for one hour at 300° C. before being analyzed using standard procedures outlined by Berger and Killingley (1977). Isotopic values for oxygen were expressed in the usual $\delta^{18}O$ notation with respect to the PDB standard. The measurements are precise to about 0.1 $^{0}/_{00}$.

The resultant isotopic data show a distinct offset to higher $\delta^{18}O$ values for the midden shell (Fig. 2a) compared to those for the modern shell (Fig. 2b). Based on average monthly ocean temperature and salinity data for the years 1973 through 1982 on the coast at San Clemente (just south of CA-ORA-855), expected calcite $\delta^{18}O$ values (Fig. 2c) were calculated using the paleotemperature equation of Epstein et al. (1953) and $\delta^{18}O$ salinity (water) relationships (Craig and Gordon 1965). The coincidence of the range of calculated $\delta^{18}O$ values (-1.5 to 0.5 $^{0}/_{00}$) and the values measured for modern shell (-1.5 to 0.5 $^{0}/_{00}$), we believe, establishes the accuracy of the method and therefore permits an interpretation of the midden shell data in terms of temperature.

The midden shell samples have a mean $\delta^{18}O$ value of 0.133 (±0.428) with respect to PDB, which translates into a mean temperature of 13.5° (±1.8°) C. if the isotopic composition of prehistoric ocean water is assumed to have been similar to that of today. A mean temperature of 16.4° (±2.2°) C. for the 1973 - 1982 period compares well with a 50-year mean temperature of 16.8° (±2.5°) C. reported for La Jolla, roughly 60 km. south of San Clemente (S. A. Tont, personal communication 1983). Assuming comparable prehistoric and modern ocean salinities in the

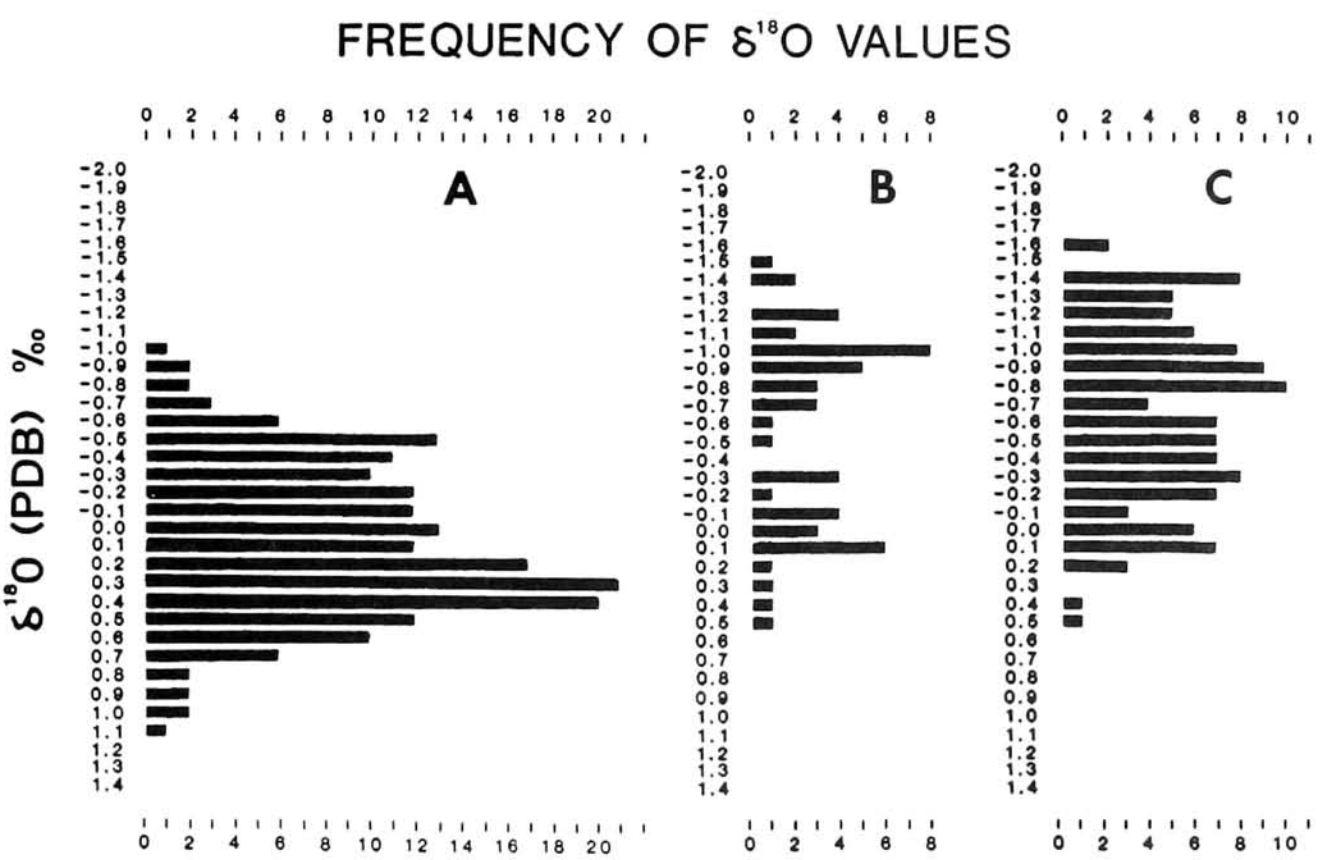

Fig. 2. Calcite $\delta^{18}O$ values for 14 *Mytilus californianus* shells recovered at a depth of 30-90 cm. from CA-ORA-855 (a) and three modern *M. californianus* shells from Dana Point, California (b); expected calcite $\delta^{18}O$ values (c, see text for explanation).

region, $\delta^{18}O$ analysis indicates that the midden shell grew in ocean surface water approximately 3.0° C. colder than at present along the southern California coast. Major changes in sea-surface temperatures have been related to changes in the level of solar activity (Pisias 1978), although oxygen isotopic analysis of foraminifera in varved sediments of the Santa Barbara Basin suggests that increased upwelling during the Little Ice Age (Dunbar 1981) may account for some of this temperature differential (Tont 1975).

Local air and ocean temperatures show a close relationship along the west coast of the United States (Hubbs 1948; Roden 1966; Hannes 1974), and Tont (1976) demonstrated an excellent positive correlation between sea-surface and air temperatures for coastal southern California. Therefore, it can be inferred that air temperatures were also correspondingly cooler in the area of San Juan Capistrano during the Little Ice Age.

Warm ocean surface temperatures off southern California increase atmospheric water vapor and thus often lead to increased onshore rainfall, while cooler waters tend to be associated with greater aridity (Namias 1969; Pisias 1978, 1979; see also Soutar and Crill 1977). However, given the magnitude of increased effective moisture indicated for California during the Little Ice Age (Moratto, King, and Woolfenden 1978), generally more moist conditions probably prevailed in the region as the result of lower temperatures and correspondingly lower rates of evaporation (cf. Antevs 1955).

In sum, Little Ice Age climatic patterns detrimental to hunter-gatherer subsistence economies in southern California seem unlikely (see Johnson 1977). Although oxygen isotopic analysis of ancient and modern shell suggests a climatic shift along the coast comparable to that recognized in other regions, late prehistoric populations do not appear to have been adversely affected. The lack of evident human impact may also reflect a broad base of subsistence resources and hunter-gather adaptive strategies that ameliorated the effects of variable resource availability and productivity.

ACKNOWLEDGEMENTS

We acknowledge the valuable comments of W. H. Berger, P. J. Wilke, and C. W. Meighan, and the assistance of Don Hanna, Carole Magnusson, Pat Lynch, Ken Stumpff, Peter J. Slota, Jr., Louis A. Payen, and Christine Prior. The work was supported in part by the National Science Foundation (OCE 83-14984 [J. S. Killingley] and BNS 82-11804 [R. E. Taylor]) and funds provided by Saffell and McAdam, Inc., Irvine, California. This is contribution 85/1 of the Institute of Geophysics and Planetary Physics, University of California, Riverside.

REFERENCES

Antevs, Ernst
1955 Geologic-Climatic Dating in the West. American Antiquity 20(4): 307-335.

Berger, Wolfgang H., and John S. Killingley
1977 Glacial Holocene Transition in Deep-Sea Carbonates: Selective Dissolution and the Stable Isotope Signal. Science 197: 563-566.

Bray, J. Roger
1965 Forest Growth and Glacier Chronology in Northwest North America in Relation to Solar Activity. Nature 205: 440-443.

1971 Solar-Climate Relationships in the Post-Pleistocene. Science 171: 1242-1243.

1974 Glacial Advance Relative to Volcanic Activity Since 1500 A.D. Nature 248: 42-43.

Calder, Nigel
1975 The Weather Machine. New York: The Viking Press.

Craig, H., and L. I. Gordon
1965 Deuterium and Oxygen 18 Variations in the Ocean and Marine Atmosphere. In: 2nd Conference on Stable Isotopes in Oceanographic Studies and Paleotemperatures, E. Tongiorgi, ed., pp. 9-130. Rome: Consiglio Nazionale delle Richerche.

Denton, George H., and Wibjörn Karlén
1973 Holocene Climatic Variations – Their Pattern and Possible Cause. Quaternary Research 3: 155-205.

Druffel, Ellen M.
1982 Banded Corals: Changes in Oceanic Carbon-14 During the Little Ice Age. Science 218: 13-19.

Dunbar, Robert B.
1981 Sedimentation and the History of Upwelling and Climate in High Fertility Areas of the Northeastern Pacific Ocean. Ph.D. dissertation, University of California, San Diego.

Eddy, J. A.
1977 The Case of the Missing Sunspots. Scientific American 236: 80-92.

Epstein, S., R. Buchsbaum, H. A. Lowenstam, and H. C. Urey
1953 Revised Carbonate-Water Isotopic Temperature Scale. Geological Society of America Bulletin 64: 1315-1326.

Gribbin, John, and Hubert H. Lamb
1978 Climatic Change in Historical Times. In: Climatic Change, J. Gribbin, ed., pp. 68-82. London: Cambridge University Press.

Hannes, Gerald
1974 Factor Analysis of Coastal Air and Water Temperature. Journal of Applied Meteorology 13: 3-7.

Hubbs, Carl L.
1948 Changes in the Fish Fauna of Western North America Correlated with Changes in Ocean Temperature. Journal of Marine Research 7: 459-482.

Johnson, Donald Lee
1977 The Late Quaternary Climate of Coastal California: Evidence for the Ice Age Refugium. Quaternary Research 8: 154-179.

Killingley, John S., and Wolfgang H. Berger
1979 Stable Isotopes in a Mollusk Shell: Detection of Upwelling Events. Science 205: 186-188.

Kington, J. A.
1980 Daily Weather Mapping from 1781. Climatic Change 3: 7-36.

Koerper, Henry C.
1981 Prehistoric Subsistence and Settlement in the Newport Bay Area and Environs, Orange County, California. Ph.D. dissertation, University of California, Riverside.

Koerper, Henry C., and Christopher E. Drover
1983 Chronology Building for Coastal Orange County: The Case from CA-Ora-119-A. Pacific Coast Archaeological Society Quarterly 19(2): 1-33.

Lamb, Hubert H.
1977 Climate, Past Present and Future, 2, Climatic History and the Future. London: Methuen and Co.

Lindgren, S., and J. Neumann
1981 The Cold and Wet Year 1695 – a Contemporary German Account. Climatic Change 3: 173-187.

Moratto, Michael J., Thomas F. King, and Wallace B. Woolfenden
1978 Archaeology and California's Climate. The Journal of California Anthropology 5(2): 147-161.

Namias, Jerome
1969 Use of Sea-Surface Temperatures in Long Range Predictions. World Meteorological Organization Technical Note No. 103.

O'Neil, Stephen, and Nancy Evans
1980 Notes on Historical Juaneño Villages and Geographical Features. Journal of California and Great Basin Anthropology 2(2): 226-232.

Pisias, Nicklas G.
1978 Paleoceanography of the Santa Barbara Basin During the Last 8000 Years. Quaternary Research 10: 366-384.

1979 Model for Paleoceanographic Reconstructions of the California Current During the Last 8000 Years. Quaternary Research 11: 373-386.

Roden, Gunnar I.
1966 A Modern Statistical Analysis and Documentation of Historical Temperature Records in California, Oregon and Washington, 1821 - 1964. Journal of Applied Meteorology 5: 3-24.

Schneider, Stephen H., and Clifford Mass
1975 Volcanic Dust, Sunspots and Temperature Trends. Science 190: 741-746.

Soutar, Andrew, and Peter A. Crill
1977 Sedimentation and Climatic Patterns in the Santa Barbara Basin During the 19th and 20th Centuries. Geological Society of America Bulletin 88: 1161-1172.

Stuvier, M., and P. D. Quay
1980 Changes in Atmospheric Carbon-14 Attributed to a Variable Sun. Science 207: 11-19.

Tont, Sargun A.
1975 The Effect of Upwelling on Solar Irradiance Near the Coast of Southern California. Journal of Geographical Research 80(36): 5031-5034.

1976 Short-Period Climatic Fluctuations: Effects on Diatom Biomass. Science 194: 942-944.

Wallace, William J.
1955 A Suggested Chronology for Southern California Coastal Archaeology. Southwestern Journal of Anthropology 11(3): 214-230.

Early Holocene Settlement and Subsistence in Relation to Coastal Paleogeography: Evidence from CA-SBA-1807

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During the summer of 1984, archaeological investigations on the coast west of Santa Barbara provided preliminary data from an early Milling Stone site (CA-SBA-1807) dating to 8,000 radiocarbon years B.P. Radio-

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